Quantifying Performance of Succulents and Novel Substrates for Extensive Green Roof Applications in the US Pacific Northwest

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Background

This study aims to improve the performance of extensive green rooftops using native plant species under minimal maintenance and irrigation regimens. Methods involved developing three new soil profiles specifically for the installation sites where we built an array of 15 containers, each filled with 18 liters of soil, and planted a total of 60 succulents native to the US Pacific Northwest. Species tested included *Dudleya lanceolata*, *Sedum album*, *S. laxum, S. oreganum, S.* 'Silver Moon', and *S. spathulifolium*. The three substrate types we designed included varying mixes of organic compost, sand, vermiculite, perlite, and pea gravel, arranged in distinct profiles, and instrumented with soil moisture sensors. Remote automated weather stations also measured air temperature and dew points at multiple heights above each rooftop, along with precipitation, wind speed, wind direction, incoming photosynthetically available radiation, broad-spectrum solar radiation, and leaf wetness. Other measurements included infrared and visible-wavelength photography of plant health from stands we designed for this study, along with traditional and novel digital transect surveys of plant performance.

Study Area

This study involved the rooftops of three buildings on the University of Portland campus (labeled in aerial photo below) in Portland, OR, which averages 66 cm of liquid-water-equivalent precipitation from October to April, and little to no rainfall during summer months. These buildings varied in aspect, exposure, and winds, along with proximity to nearby trees, water bodies, and urban heat sources.

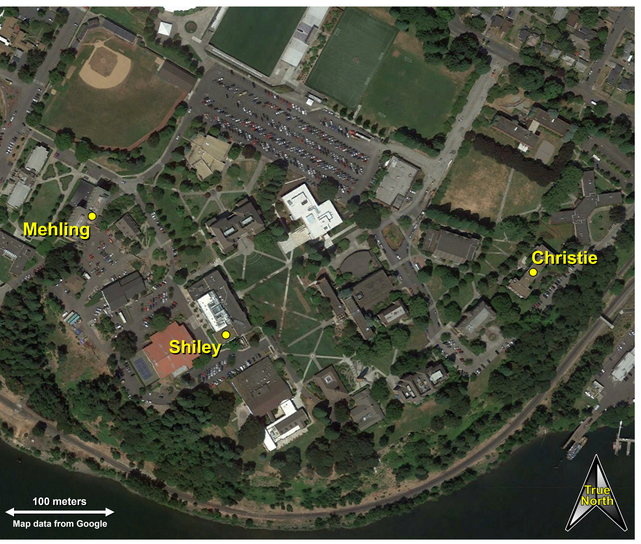

Figure 1. Study area in North Portland, Oregon

Infrared Temperatures (°C) of Selected Containers at ~3pm Local Time

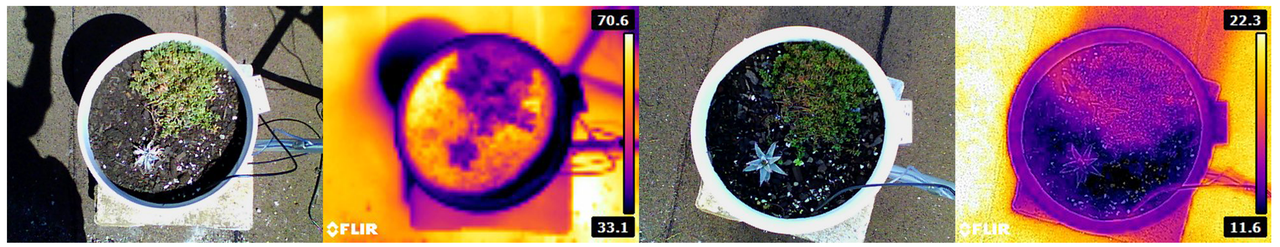

Figure 2. *S. album* and *Dudleya lanceolata* on Christie: Aug 7, 2014 (left) and Oct 21, 2014 (right)

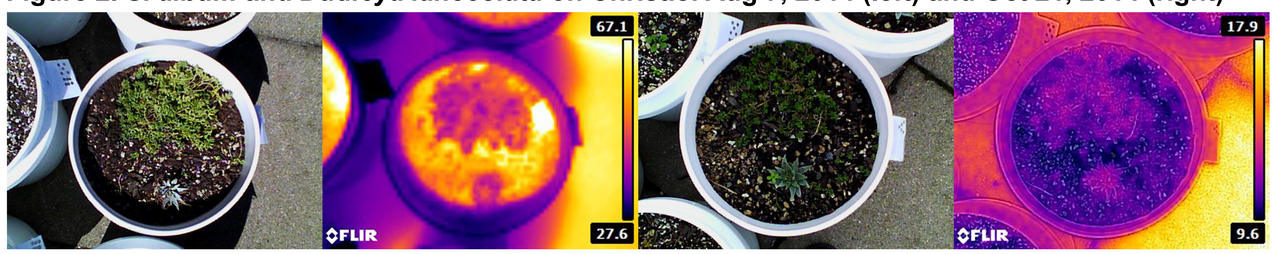

Figure 3. *S. album* and *Dudleya lanceolata* on Mehling: Aug 7, 2014 (left) and Oct 21, 2014 (right)

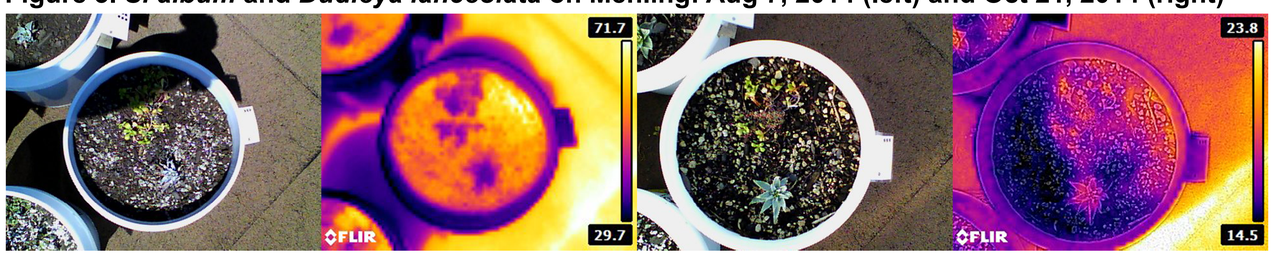

Figure 4. *S. spathulifolium* and *Dudleya lanceolata* on Christie: Aug 7, 2014 (left) and Oct 21, 2014

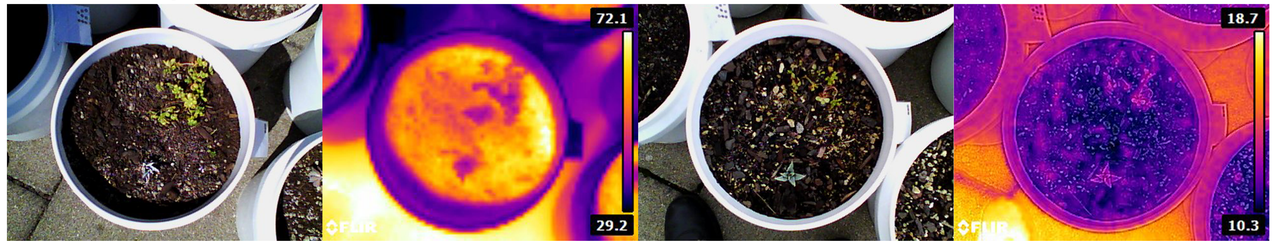

Figure 5. *S. spathulifolium* and *Dudleya lanceolata* on Mehling: Aug 7, 2014 (left) and Oct 21, 2014

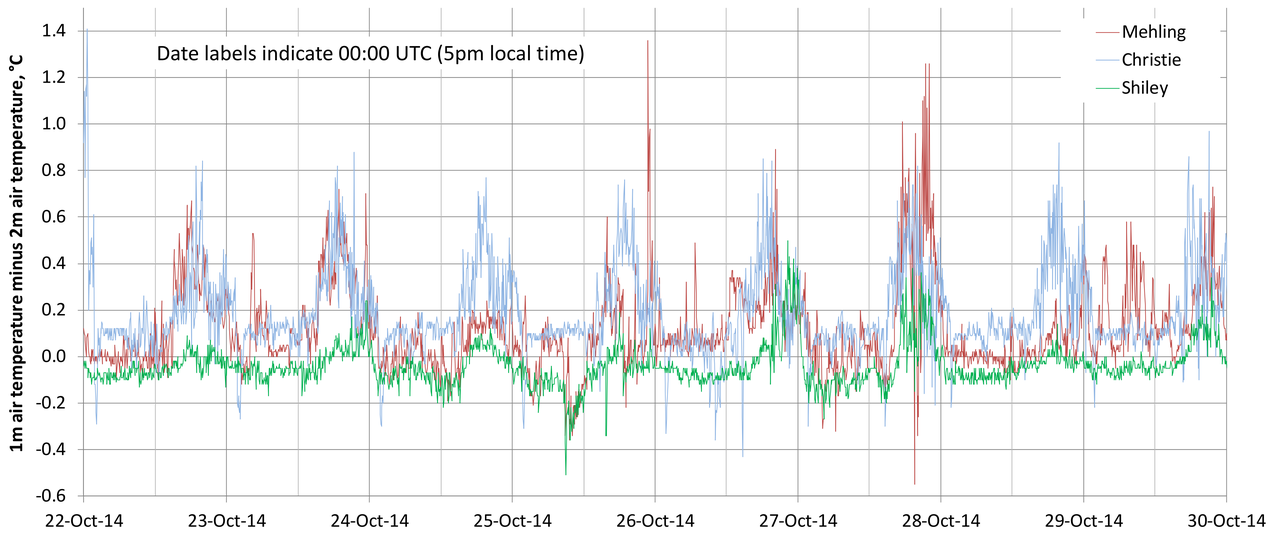

Figure 6. Positive numbers quantify upward sensible heat flux from the rooftop, which can indicate wasted energy from furnace systems at night, or from air conditioning (if present) during the day

Impact on Hydrology and Ecology

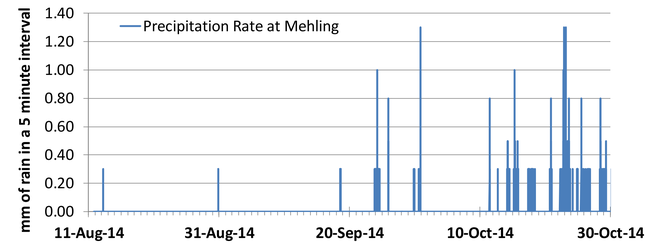

Figure 7. Precipitation measured at Mehling Hall

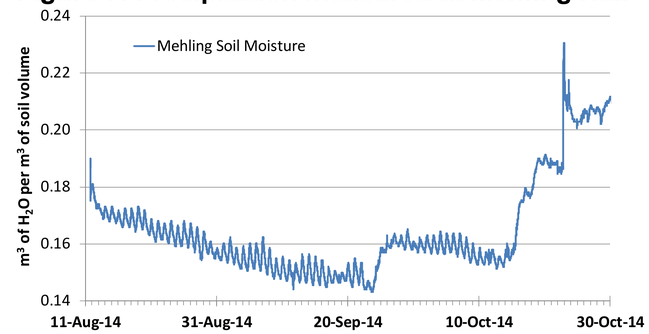

Figure 8. Soil moisture under *S. album* and *Dudleya lanceolata* on Mehling Hall (in Figure 3)

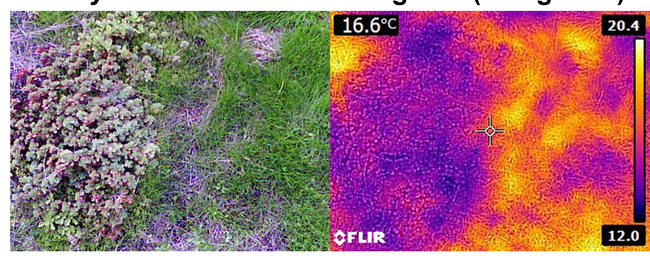

Figure 9. Areas on left: mostly native species; right: mostly invasives, ~3pm local, Oct 21, 2014

Conclusions

Infrared images show extreme temperature differences between concrete rooftops and substrate/vegetation on summer afternoons. This shows how a green roof can reduce building temperatures during summer. Nighttime air temperature measurements also show how much green rooftops can reduce the amount of energy wasted through heating losses in the cool season.

Infrared temperature of invasive species versus the native *Sedum* species shows that even when not senesced, as the invasive species were for the majority of the summer, invasives do not mitigate rooftop temperatures as much as natives do.

All three substrates designed by this study have handled summertime water retention and rainy-season drainage needs successfully so far. All *Sedums* and *Dudleyas* survived the summer of initial establishment but some species have exhibited noticeably faster growth than others have.